

The Galactic Transient Sky with *Swift*

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Abstract

The unique capabilities of *Swift* that make it ideal for discovery and follow-up of Gamma-Ray bursts also makes it the ideal mission for discovery and monitoring of X-ray Transients in the Milky Way and the Large and Small Magellanic Clouds. The Burst Alert Telescope allows for detection of new transient outbursts, the automated follow-up capabilities of *Swift* allow for rapid observation and localization of the new transient in X-rays and optical/UV bands, and *Swift*'s rapid slewing capabilities allows for low-overhead short observations to be obtained, opening up the possibility of regular, sensitive, long term monitoring of transient outbursts that are not possible with other currently operational X-ray missions. In this paper I describe the methods of discovery of X-ray transients utilizing *Swift*'s BAT and also collaboration with the MAXI telescope. I also detail two examples of X-ray transient science enabled by *Swift*: *Swift* discovery and monitoring observations of MAXI J1659–152, a Black Hole candidate Low Mass X-ray Binary in the Galactic Halo, which has the shortest known orbital period of any such system; and *Swift* monitoring of IGR J00569–7226, an edge on Be/X-ray binary that displayed a outburst in 2013 and 2014, and which monitoring by *Swift* allowed for detection of dips, eclipses and the determination of the orbital parameters, utilizing a measurement of doppler shifts in the pulsar period.

Keywords: Swift, X-ray Transient, Black Hole, Neutron Star, MAXI J1659–152, IGR J00569–7226

1. Introduction

The flare-up of an X-ray transient typically signals a rapid increase in the rate of accretion onto a compact object, a white dwarf (WD), neutron star (NS) or black hole (BH), and provides an ideal laboratory for studying astrophysics in a relativistic regime. Even though transients have been studied for many years, our understanding of the processes behind extreme accretion events remains relatively poor. The term X-ray transients cover a wide range of different system phenomenology, but is typically used to mean Low Mass X-ray Binary (LMXB) and High Mass X-ray Binary (HMXB) systems containing BH and NS secondaries. However, it may also refer to a wide range of transient X-ray phenomena including millisecond pulsars (e.g. Campana et al. 2008), magnetar outbursts (e.g. Kennea et al. 2013), Stellar Flares (e.g. Drake et al. 2014) and many others.

The process of accretion that drives most X-ray astrophysical phenomena can often be dramatic and short lived, with increase in accretion rates causing X-ray flux rises of up to 6 orders of magnitude, in the case of Supergiant Fast X-ray Transients (Romano et al. 2014 and references therein), from quiescent levels. In many cases these events lead to the discovery of previously unknown systems, or systems that were previously considered uninteresting. These transient events are rare and often short lived, making detection and detailed study difficult. Other transients outbursts may be from sources that were previously known outbursts, but have not been seen for many years, for example BH transient outbursts are known to be recurrent, but the time between outbursts has been reported to be as long as 60 years (Eachus et al., 1976). To obtain a good rate of de-

tection of transient outbursts, X-ray instruments that cover very large areas of the sky are required.

However, wide field and all-sky instruments, such as *Fermi* GBM (Meegan et al., 2009), *MAXI* (Matsuoka et al., 2009), *INTEGRAL* ISGRI (Lebrun et al., 2003) and *RXTE* ASM (Bradt et al., 1993), typically lack the spatial resolution required to provide accurate localizations necessary for further optical and IR observations, and typically do not have enough sensitivity for a detailed analysis of the characteristics of the outburst.

NASA's *Swift* mission (Gehrels et al., 2004) was designed to localize bright X-ray transient events, in this case Gamma-Ray Bursts (GRBs). Its three instruments, the Burst Alert Telescope (BAT; Barthelmy et al. 2005), the X-ray Telescope (XRT; Burrows et al. 2005) and UV/Optical Telescope (UVOT; Roming et al. 2005), provide a unique complement of instruments to discover and follow-up Gamma-Ray bursts. This combined with a spacecraft that provides very rapid and accurate slewing to a target, allows for reporting of Gamma-Ray burst positions within minutes of them being detected.

The same capabilities that make *Swift* so successful at finding GRBs, are equally as well tuned for discovery and localization of bright X-ray Transients. In addition the rapid slewing capabilities of *Swift* allows for low-overhead short ($\sim 1 - 2$ ks) observations to be taken, allowing for long-term sensitive monitoring of outbursts to be performed. No other operating mission is capable of high cadence monitoring outbursts in this manner.

In this paper I will explore *Swift*'s ability to detect, localize and follow-up X-ray transients in the Milky Way and the Large

and Small Magellanic Clouds, as both a stand-alone telescope and in concert with other X-ray/Gamma-Ray wide field detectors utilizing the *Swift* Target of Opportunity (ToO) program.

2. *Swift* discovery and localization of X-ray Transients

Swift performs observations of new X-ray transients utilizing triggers from both the BAT and from other wide field X-ray and Gamma-ray observatories. In this section I will describe the various methods of detection and follow-up that are commonly used to enable X-ray Transient science with *Swift*.

2.1. BAT Triggered X-ray Transients

The BAT covers approximately 1.4 steradian of the sky at any one time, and due to *Swift*'s diverse observing strategy, both caused by the large number of targets observed in a typical day, and by the need observe at least 3 targets per 96 minute orbit in order to avoid looking too close to the Earth, BAT on average covers 80–90% of the sky daily (Krimm et al., 2013). Such near all-sky coverage means that it is excellent at detecting new X-ray transients that emit in the 15–150 keV BAT energy range.

When BAT detects a bright unknown transient, it triggers the *Swift* “automated target” (AT) response, which is the same response for GRBs: The BAT localization of the transient, with an error of typically ~ 3 arc-minutes, is telemetered to the ground through the Tracking and Data Relay Satellite System (TDRSS), and if possible *Swift* will slew to the coordinates of the transient, and begin follow-up observations with the UVOT and XRT instruments. All *Swift* TDRSS telemetered products are distributed through the Gamma-ray Coordinates Network (GCN; Barthelmy et al. 1995), enabling community follow-up of newly discovered transients.

When observations begin, the XRT takes a series of short images of the field (0.1 s and ~ 2.5 s long) and attempts to locate the transient utilizing an onboard centroiding algorithm. If the transient is bright enough to be detected in this exposure, this location will be telemetered to the ground through TDRSS within minutes of the initial detection. XRT will perform observations in Auto state, where the CCD will be read out in either in Windowed Timing (WT) or Photon Counting (PC) mode based on the brightness of the new transient (for a description of XRT modes see Hill et al. 2004. If PC mode data is taken, event data are telemetered to the ground through TDRSS for the first orbit, and event reconstruction and astrometric correction, utilizing UVOT data (e.g. Evans et al. 2009), allows for a position to be determined with accuracies up to 1.5 arc-seconds radius, with XRT data alone allowing an accuracy of up to 3.5 arc-seconds radius (all errors quoted at 90% confidence). UVOT also takes observations of the field and telemeters these through TDRSS, allowing for a rapid localization of any optical counterparts of the transient within minutes of detection (see for example, Figure 1).

BAT triggered response allows for very rapid reporting of the location of a new X-ray transient to the community, typically within seconds of detection through GCN alerts, and approximately 10–25 minutes through GCN Circulars. In addition for



Figure 1: Example of the localization of an X-ray transient with UVOT, in this case the transient is the blue star in a cluster of three objects near the center of the image.

X-ray transients, the *Swift* team will issue a report on the coordinates, along with a preliminary spectral analysis to the Astronomers Telegram website (ATel), which is the most common way of reporting new transients in the X-ray transient community.

2.2. The *Swift*/BAT Hard X-ray Transient Monitor

In addition to transients detected by the BAT triggering algorithm, the The *Swift*/BAT Hard X-ray Transient Monitor (Krimm et al., 2013) is a software based transient monitor that utilizes BAT data taken during normal observations. The BAT Transient Monitor has a sensitivity of approximately 5.3 mCrab in a day, allowing for the monitoring of many bright known sources, as well as the detection of new transients. The primary benefit is the ability to detect sources down to a much fainter level than needed to trigger BAT (100–200 mCrab, D. Palmer, *private communication*), meaning slow-rising transients can be detected much earlier than with BAT itself.

The *Swift*/BAT Hard X-ray Transient Monitor web site contains light curves for over 1000 sources, with approximately 250 of these being detected on a daily basis. Since February 2005 it has discovered ~ 20 new X-ray transients. An example of an light-curve of an X-ray transient discovered by the BAT Transient Monitor, *Swift* J1753.7–2544 (Krimm et al., 2013), is shown in Figure 2.

When a new transient is discovered using this method, observations are triggered through the *Swift* Target of Opportunity (TOO) program, and follow-up typically consists of a short PC mode observation in order to localize the source, follow-up by observations in WT in order to characterize the spectrum and timing nature of the source. Results of these observations are reported by the *Swift* team by ATel. Typically these are sent out within days of the source rising above the detection limit of BAT.

2.3. The *Swift* Target of Opportunity Program

In addition to triggers from BAT, *Swift* performs observations of the new transients detected by other missions, e.g. *INTEGRAL* (Winkler et al., 2003) and *Fermi/LAT* (Atwood et al.,

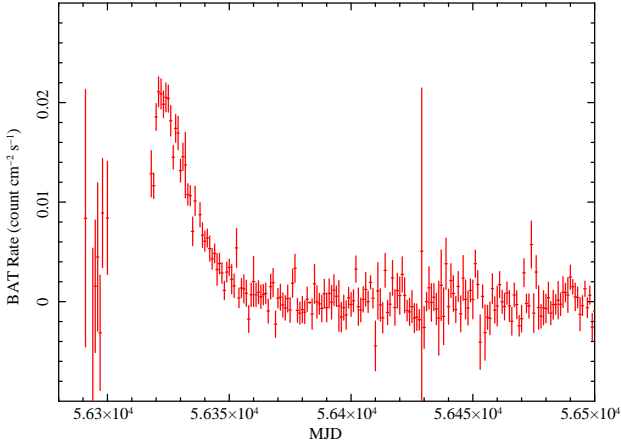


Figure 2: *Swift*/BAT Hard X-ray Transient Monitor light curve of Swift J1753.7–2544 with daily bins. Swift J1753.7–2544 was first detected on January 24th, 2013.

2009), through the *Swift* Target of Opportunity program. The *Swift* TOO program is open to the astronomical community via the *Swift* Mission Operations Center (MOC) website¹, and enjoys a high degree of popularity, for example, in 2014 951 TOO requests were submitted.

Swift TOOs can be submitted with a variety of priority levels, which relate to how quickly observations should be performed. Priority 1 (within 4 hours) and Priority 2 (within 24 hours) when submitted will alert the *Swift* Observatory Duty Scientist (ODS) via mobile phone text message, at which point they will begin evaluating the feasibility of the requested observations. Priority 3 (days to a week) and Priority 4 (weeks to a month), alert the ODS via email. All TOO requests require approval of the *Swift* Principle Investigator and/or their deputy before execution.

Swift has the capability of performing automated TOO observations through ground commanding. Given the targets coordinates, a requested exposure time and priority level, *Swift* will automatically determine the target visibility and observe the target for the requested amount of time, interleaving observations between targets in the current observing plan based on the priority. These TOO commands can be uploaded to the spacecraft utilizing either TDRSS or ground station commanding. TDRSS commanding requires manual intervention of the *Swift* Flight Operations Team (FOT), so is typically only available during working hours, although in some high priority cases, FOT members will be called into the *Swift* MOC to perform out-of-hours commanding.

A customized scheduling system developed by the *Swift* Science Operations Team (SOT) allows for TOO commanding to be scheduled for a future ground station pass at any time of the day, allowing for out-of-hours TOO commanding without the need to call in FOT members. *Swift* typically has 10 ground station passes per day, meaning that it can be on-target of any TOO request typically within a few hours at any time of the day.

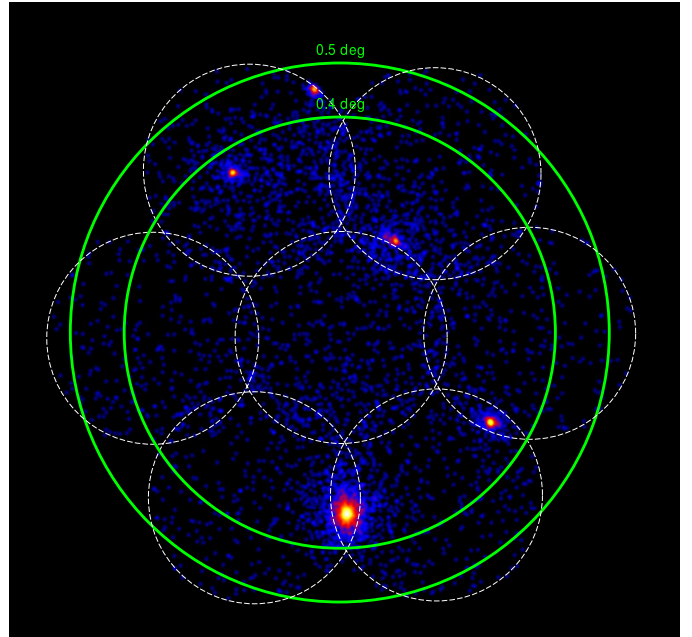


Figure 3: Example of a *Swift* 7-point tiling observation to identify a new transient near the Galactic Center. Marked in green are the 0.4 deg error circle that gets $\sim 100\%$ coverage, and the 0.5 deg error circle that gets $\sim 95\%$ coverage. Individual XRT pointings are shown as white dashed circles. In this field, the brightest X-ray source is A1745-294, other sources are all known transients around Sgr A*.

In addition to single-observation TOOs, *Swift* may observe multiple locations in order to cover a larger error region than allowable in a single pointing. There are two ways in which this can be achieved: by utilizing multiple TOO uploads of differing coordinates in order to cover a large error box; and by utilizing the BAT tiling script, which allows for automated tiling of circular error regions. The former technique is typically used only for imaging extremely elongated error regions, such as those from the InterPlanetary Network (IPN; e.g. Cline et al. 1999).

The BAT tiling script allows for tiling of regions utilizing a 4- or 7-point tiling pattern. An example of the 7-point tiling pattern can be seen in Figure 3. The 7-point tiling guarantees coverage of an error circle up to 0.4 degrees radius at $\sim 100\%$ coverage, and $\sim 95\%$ coverage of a radius of 0.5 degrees. The benefit of this method is that as the slews between the individual tiles are very small, they can be performed quickly and with a low overhead, often allowing for imaging of the entire error circle in a single *Swift* orbit. Given that Galactic X-ray Transients are typically bright, observations consisting of seven tiles of 200 seconds exposure each are common. This greatly enhances the ability of *Swift* to localize transients, even with larger error boxes. As the BAT tiling script can be executed through the regular TOO commanding, it places no additional burden on the ODS and SOT, unlike the manual tiling of error boxes, which would require many more TOO commands to be organized.

¹<http://www.swift.psu.edu>

2.4. Monitor of the All-Sky X-ray Image

Although BAT is very capable at detection of an X-ray Transient outburst, its energy range (15-150 keV) means that is tuned for detection of transients with relatively hard spectra. This tends to favor BH transients over NS transients, that often have spectra that break above 10 keV. In order to increase the number of X-ray Transient detections by *Swift*, the *Swift* team partnered with the team of JAXAs “*Monitor of the All-Sky X-ray Image*” telescope (MAXI; e.g. Matsuoka et al. 2009), which is part of the Japanese Experiment Module on the International Space Station. MAXI is a scanning telescope consisting of two instruments, the Gas Slit Camera (GSC; Mihara et al. 2011) and Solid-state Slit Camera (SSC; Tomida et al. 2011).

Both MAXI instruments are one-dimensional coded mask slit instruments, and scan majority of the sky every 86 minute ISS orbit. MAXI provides a powerful tool for the discovery of new X-ray transients, collecting an X-ray image of the sky in the 0.5-20 keV energy band, with sensitivities as low as 60 mCrab (5 sigma) in a single orbit and 15 mCrab in a day. New transient discoveries are reported by the MAXI Nova Alert system (Negoro, 2009) via email communication.

For sources that are relatively stable, MAXI can localize a point source with an error of approximately 12 arc-minutes radius (90% confidence). This matches well the field of view of XRT (~ 11.8 arc-minutes radius), meaning that typically MAXI error circles can be covered with a single pointing of XRT. Given that MAXI transients are typically > 15 mCrab in brightness, detection by XRT is assured in an a short (500-1000s) exposure, as XRTs sensitivity equates to approximately 1 XRT count/s/mCrab. Fainter and/or temporally variable MAXI transients may have larger error circles, which require tiling observations to be performed.

The *Swift* and MAXI teams have set up a collaboration that, through the *Swift* Guest Investigators Program, follow-up the detection of all new MAXI detected transients with *Swift* TOO observations in order to confirm and accurately localize the new transient. These observations are then typically followed by monitoring observations of this new transient to track its entire outburst.

3. Selected Transient Results from *Swift*

Here I report on the results of *Swift* observations two X-ray transients. Firstly I cover MAXI J1659–152, a black hole LMXB in the Galactic Halo which was discovered by *Swift*. Secondly I cover *Swift* observations of IGR J00569–7226 (also known as SXP 5.05), which was discovered by *INTEGRAL*, but which *Swift* observations allowed the discovery of both eclipses, and measurement of the orbital parameters utilizing doppler shifts in the pulsar period.

3.1. MAXI J1659–152

MAXI J1659–152, a BH LMXB system, was first reported after detection by BAT at 08:05 UT, September 25, 2010. Follow up observations performed by the XRT and UVOT 31

minutes later localized the transient (Mangano et al., 2010), although it was initially misidentified as a GRB and named GRB 100925A. However the GRB identification was disproved when a MAXI detection ~ 5.5 hours before the BAT trigger, confirmed that MAXI J1659–152 was actually a previously unknown Galactic X-ray transient (Negoro et al., 2010).

UVOT identified a bright ($v = 16.7$) candidate inside of the XRT error circle, this counterpart did not correspond with any known catalog object. The non-detection of the companion in the USNO-B catalog allowed an upper limit to be placed on the optical brightness of MAXI J1659–152 in quiescence of $V > 21$ (Monet et al., 2003), suggesting that the optical counterpart brightened during outburst by > 4 magnitudes.

Following the detection by *Swift* and MAXI, a campaign of observations with a variety of observatories worked to identify the object. IR spectroscopy confirmed that the optical counterpart showed emission lines consistent with that of an X-ray Binary (de Ugarte Postigo et al., 2010). The transient was also detected in radio (van der Horst et al., 2010), by *INTEGRAL* (Vovk et al., 2010), *XMM-Newton* (Kuulkers et al., 2010a) and *RXTE*. *RXTE* detected a 1.6 Hz type-C QPO in the power-spectrum, which indicated that MAXI J1659–152 was a BHB (Kalamkar et al., 2011).

A 2.41 hour periodicity, first reported by Kuulkers et al. (2010b) from *XMM-Newton* data, and confirmed by Belloni et al. (2010) from *RXTE* made MAXI J1659–152 the the shortest period BHB yet known. The source of the periodicity was found to be irregular dips lasting between 5 – 40 min, with no detecting eclipses (Kuulkers et al., 2010b).

As a result of the initial *Swift* trigger, and interest in the source, *Swift* began a series of daily observations of MAXI J1659–152, covering the first 27 days of it’s outburst, after which the source became too close to the Sun for *Swift* to observe.

Results of the *Swift* monitoring can be seen in Figure 4, which shows initial outburst light curve of MAXI J1659–152 as seen by BAT, XRT and UVOT. BAT’s triggering and *Swift*’s automated slewing capability has allowed us to see a uniquely detailed and sensitive view of the early part of the outburst of a BH LMXB Transient. As can be seen in the hardness XRT ratio plot, there is considerable spectral variability seen in the initial 3-4 days of the outburst. The UVOT counterpart showed variability over all (v , b , u , $uvw1$, $uvw2$, $uvm2$) bands, correlated with the rise with the X-ray light-curve, peaking with a brightness of $v = 16.5$.

By combining XRT and BAT spectra, it was possible to track the spectral states of MAXI J1659–152 (see Figure 5. BHB are known to go through a series of canonical spectral states (e.g. see Remillard and McClintock 2006), which typically can be defined as the relative combination and strengths of emission from a thermal disk component, and a comptonized power-law component. In the early part of the outburst, MAXI J1659–152 is dominated by a hard power-law component ($\Gamma \simeq 1.8$), which quickly steepens ($\Gamma \simeq 2.8$). During the early part of the outburst, the addition of a significant but small thermal component appears, and grows hotter, indicating presence of an increasing hot disk component, which inner disk temperature rises

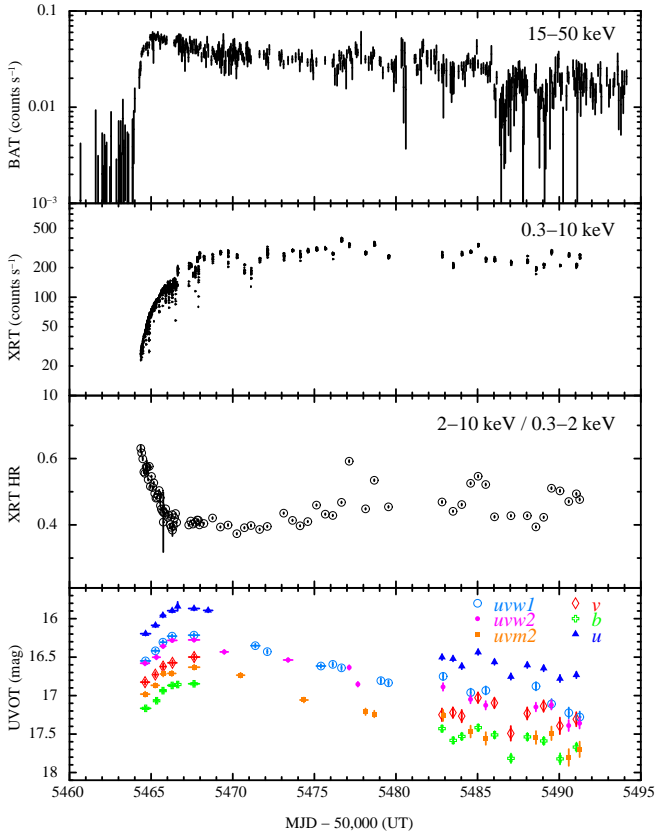


Figure 4: Outburst light-curves of MAXI J1659–152, from Kennea et al. (2011). From top to bottom: 15 – 50 keV BAT Transient Monitor light-curve with orbital binning, filtering out bins with less than 500s integration times; 0.3–10 keV XRT count rate light-curve with 100s time bins; Ratio of 2–10 keV and 0.3 – 2 keV XRT count rates, binned by orbit; UVOT six filter light-curve binned by observing segment. Errors are 1σ .

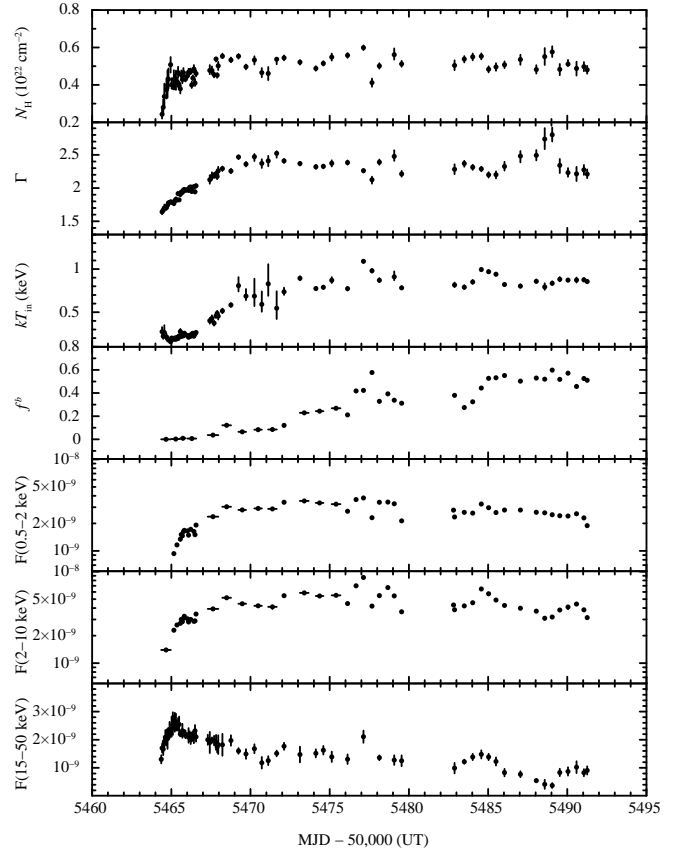


Figure 5: Time resolved spectral fitting of the XRT and BAT data from MAXI J1659–152, from Kennea et al. (2011). Evolution in fitted absorption (top panel), photon index (second panel) and inner disk temperature of the XSPEC `diskbb` model (third panel) are shown. The fourth panel shows the ratio of thermal to power-law emission, a vital measure of the state of the source, and the bottom three panels show the flux in 3 energy bands.

from $\sim .02$ to ~ 0.8 keV. However, unlike many other BHBs, MAXI J1659–152 never fully transitions into a fully disk dominated thermal state, remaining instead in an intermediate state, with the disk never contributing to more than 60% of the total emission in the 0.5–10 keV XRT energy band.

Given the estimated distance to MAXI J1659–152 of 8.6 ± 3.7 kpc (Kuulkers et al., 2013), and the height above the galactic plane ($b^{\text{II}} = 16.5$), the source lies 2.4 ± 1.0 kpc above the Galactic plane, suggesting that, similar to other BH binaries such as XTE J1118+480 (Jonker and Nelemans, 2004), it is a run-away microquasar that has been kicked out of the Galactic plane (Yamaoka et al., 2012). In fact, MAXI J1659–152 appears to belong to a sub-class of short-period galactic BH LMXBs, along with XTE J1118+480, GRO J0422+32 (e.g. Filippenko et al. 1995) and Swift J1753.6–0127 (e.g. Zurita et al. 2008) in the Galactic Halo.

Swift is particularly suited to study of this subclass of objects, as their low absorption column allows *Swift* to detect both low absorption X-ray, important for good quality continuum fitting in XRT’s soft X-ray band pass, and UV/Optical emission, which is typically too extinguished to be seen in Galactic Plane transients.

3.2. IGR J00569–7226 AKA SXP 5.05

The results discussed in this section have been published by Coe et al. (2015). Here I focus on the *Swift* contribution to that paper.

IGR J00569–7226 was first discovered by *INTEGRAL* in 2013 in scans of the Small Magellanic Cloud performed on October 25–26, 2013 and October 30–31, 2013 (Coe et al., 2013). Follow-up observations were performed by *Swift* on Nov 5th, 2013, observing the field in PC mode for 1-ks. A new X-ray transient was detected by *Swift* inside the *INTEGRAL* reported error circle at the following coordinates: RA(J2000) = 00h 57m 02.34s, Dec(J2000) = $-72^{\circ}25'55.34''$ with an estimated uncertainty of 2.6 arc-seconds radius (90% confidence). This position was consistent with the catalogued massive star NGC 330-070, a B0.5e type star. This strongly suggested that the IGR J00569–7226 was in fact the outburst of a newly discovered Be/X-ray binary system (Kennea, 2013). Archival observations of this star taken in the second phase of the Optical Gravitational Lensing Experiment (OGLE-II) show that the system has a likely 17.2 day orbital period (Schmidtke and Cowley, 2013).

The field containing IGR J00569–7226 was observed between 2006 and 2013 for a total of 25ks. Examining this archival *Swift*/XRT data showed that the source was not previously detected and that flux after initial detection by *Swift* on November 5, 2013, was 3 orders of magnitude brighter than the upper limit in those observations.

As a result of the X-ray detection, *Swift* began a series of target of opportunity observations of IGR J00569–7226. In total *Swift* performed 113 observations of SXP over a period from November 5, 2013 and March 11, 2014, at which point the transient could no longer be detected by *Swift*. The *Swift* light-curve of IGR J00569–7226 can be seen in Figure 6.

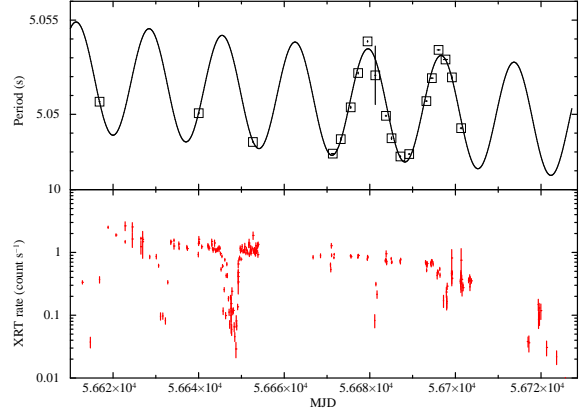


Figure 6: The outburst of IGR J00569–7226 as seen by *Swift*. Top panel: where possible, the fitted pulsar period utilizing XRT WT data, fitted to these data are a simple model of a sinusoidal variation, with a linear spin-up. Bottom panel: The XRT count rate for all observations of the source with XRT, taken at various cadences.

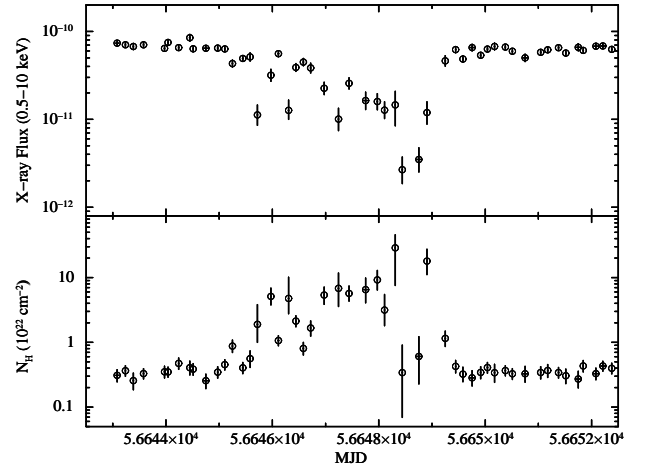


Figure 7: Adapted from Coe et al. (2015), this shows the dip and eclipse present in IGR J00569–7226, and the variation in absorption N_H seen when fitting a simple power-law model to the *Swift*/XRT spectrum. As expected with dipping source, the absorption increases with dip depth. During eclipse the absorption returns to a value consistent with the out-of-dip value, expected if the X-ray seen during eclipse are from the accretion disk corona.

The *Swift* XRT monitoring discovered the presence of broad X-ray dips and eclipses in the light curve, and combined with *INTEGRAL* observations, confirmed the presence of the 17.2 day orbital period in the X-rays (Coe et al., 2013).

In order to further study the X-ray dips, a series of high cadence observations were requested in order to cover a predicted dip starting around December 19th, 2013. The results of these observations can be seen in Figure 7, and clearly show not only a broad dipping, likely caused by attenuation by the edge of the accretion disk, but also a short eclipse of the NS by the primary star. Spectral fits of the system during the dip show the increase of absorption as the dip progresses, with the N_H value returning to the nominal value, within errors, during the eclipse, behavior that is consistent with the dip/eclipse interpretation of this light curve. Given the eclipse IGR J00569–7226 must be an near edge on system, the first edge-on Be/X-ray binary seen in the

SMC. The only other example of an edge on system, LXP 169, is in the LMC (Maggi et al., 2013) and does not show eclipses of the NS by the Be/Star.

In addition to the orbital period, *Swift*/XRT WT observations of IGR J00569–7226, combined with *XMM-Newton* observations revealed the presence of an likely 5.05s neutron star spin period. Between January 14, 2014 and March 3rd, 2014 *Swift* performed a series of 3-5 ks Windowed Timing observations of IGR J00569–7226 approximately every 2 days, after this time period the source had faded sufficiently that pulsations could no longer be detected in 5ks observations.

The objective of these observations was to accurately measure the pulsar period through at least one 17.2 day orbit, in order to measure the doppler shifts in the pulsar period caused by the orbital motion, with the aim of finding an orbital solution. Period searching of the WT data was performed utilizing a Z_2^2 test (Buccheri et al., 1983), searching with a period resolution of 1e-5 s, over 10000 steps, producing a period search range of between 5.0-s and 5.1-s. Errors on the measurement of this period were estimated utilizing the Monte-Carlo method of (Gotthelf et al., 1999). Measurements of the pulsar period in IGR J00569–7226 can be seen in the upper panel of Figure 6. Note that these data have been fit with a simple sinusoidal model combined with a linear spin-up of the pulsar by accretion.

As detailed by Coe et al. (2015), these measured periods modeled in detail in order to find the orbital parameters of the system, and find an orbital period of $P = 17.13 \pm 0.14$ and orbital eccentricity $e = 0.155 \pm 0.018$. This orbital eccentricity is low compared to other Be/X-ray binaries in the SMC, which typically have $e > 0.3$.

4. Conclusion

The *Swift* Mission’s unique complement of instruments, that allow it to be a powerful discovery machine for GRBs, also allow it to be an excellent observatory for the discovery, localization and follow-up of outbursts from X-ray Transients. *Swift* enables the rapid localization of transients discovered by its BAT instrument through automated observation, and the follow-up of transients discovered by other missions such as *MAXI*, *INTEGRAL* and *Fermi* through the *Swift* TOO program. It’s agile planning and low overhead observing capabilities allow fast turn around for observations, allowing the observatory to be on-target within hours of detection. I have given two examples of transient observations of *Swift*, which demonstrate the unique capabilities of the mission: rapid on-target observations, high cadence monitoring, timing capabilities of XRT, broad band Hard X-ray and X-ray and UV/Optical follow-up.

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